

# Camera & Image

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Dr. Tushar Sandhan

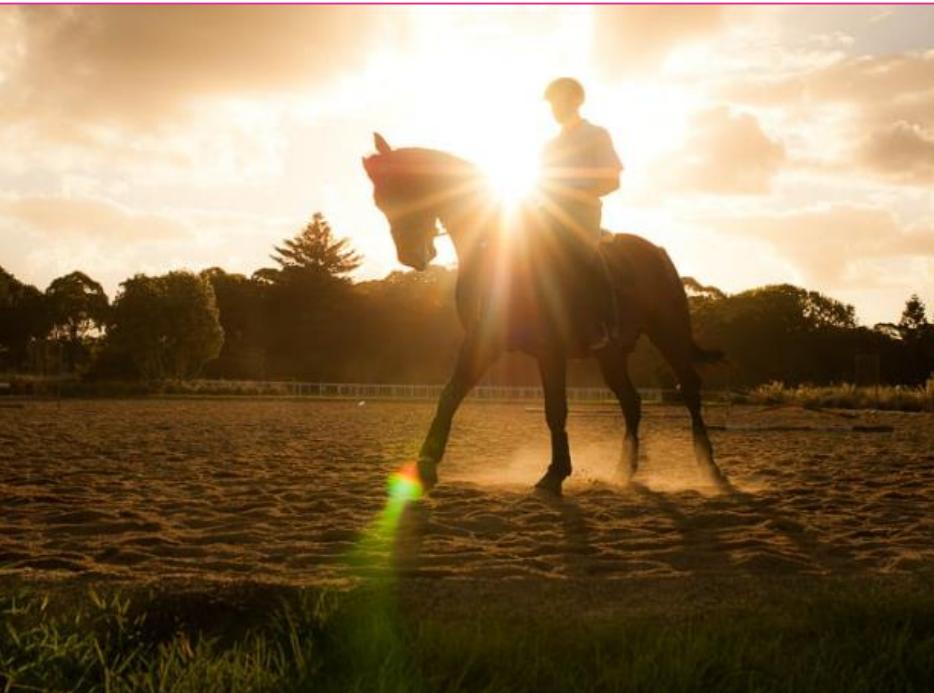
# Introduction

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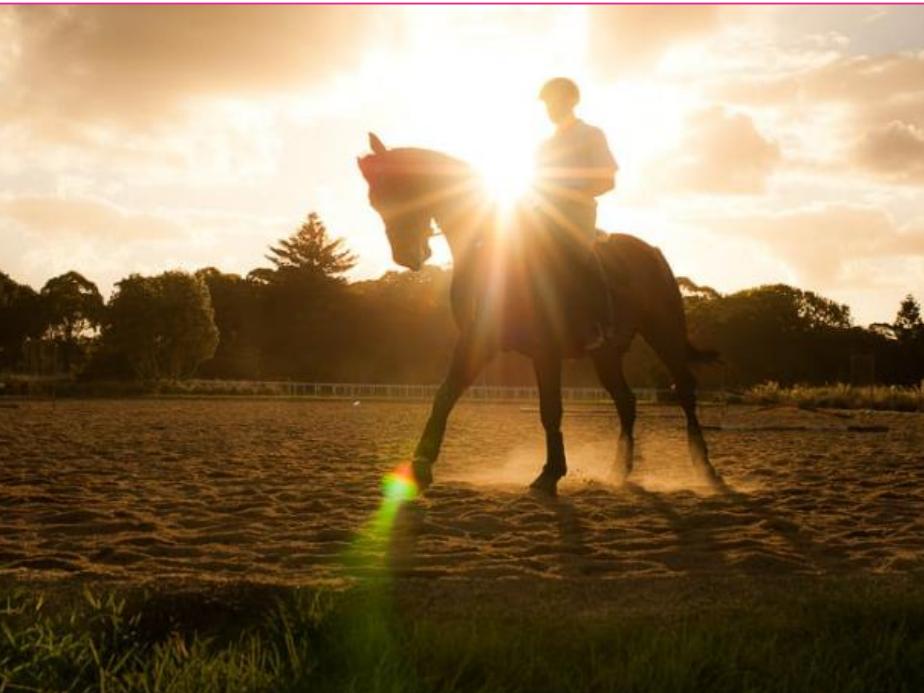
# Introduction

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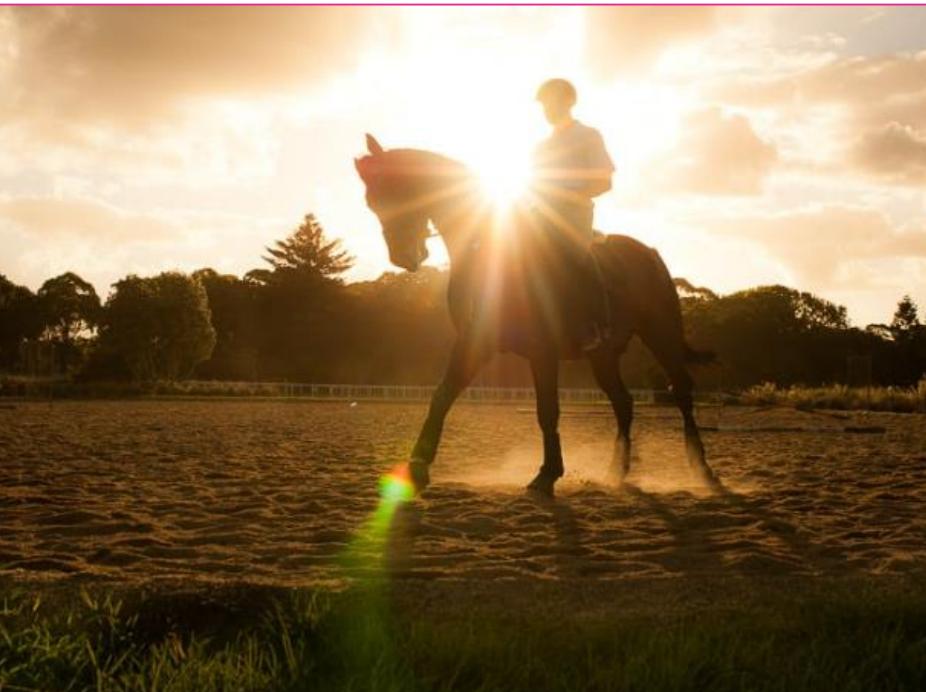
# Introduction

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- Focus



- Colors



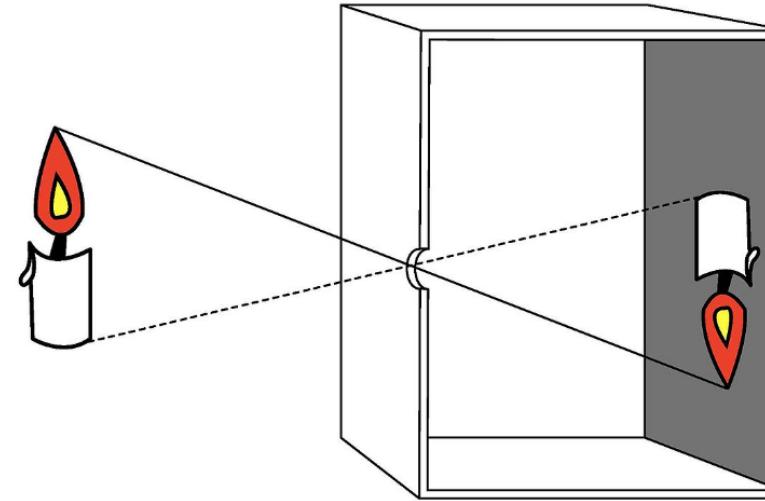
- Motions



# Aperture

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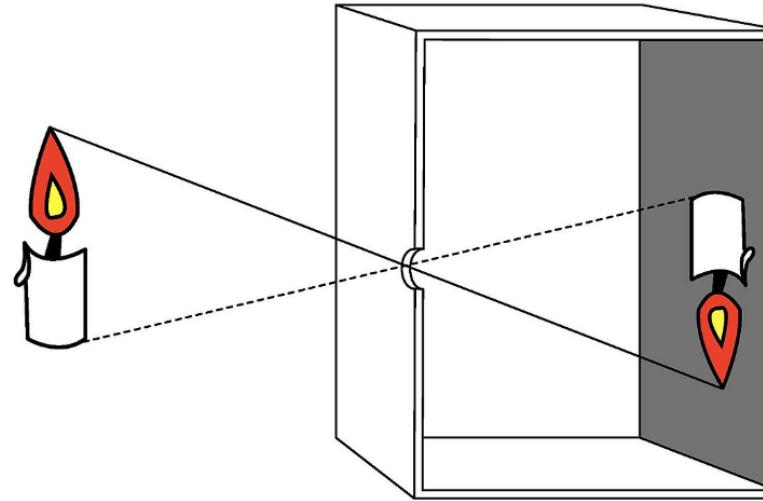
- Pinhole camera
  - without lens
  - tiny aperture
  - no lens distortions
  - everything appears in focus
    - $\infty$  DOF



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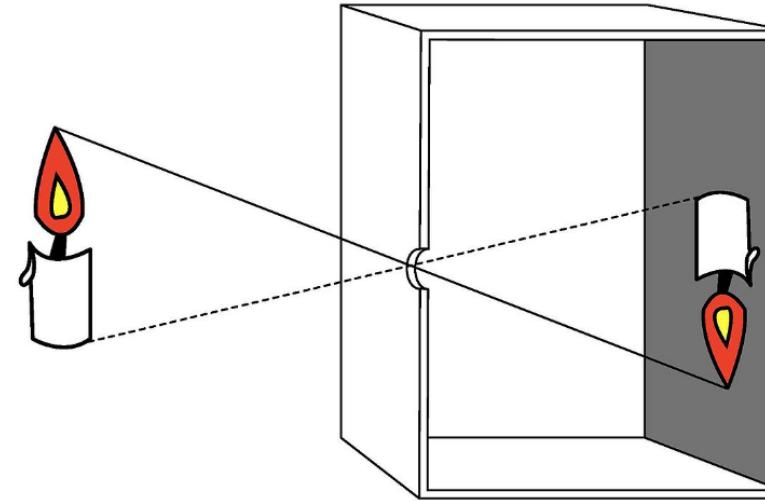


- Photography camera
  - controllable aperture

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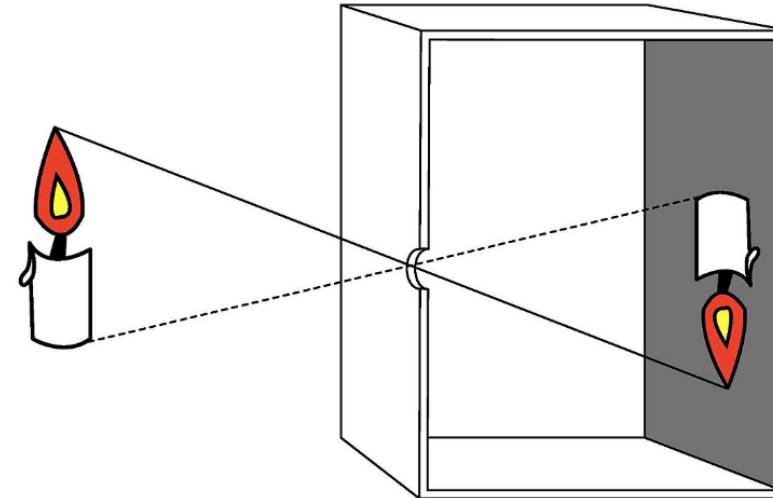


- Photography camera
  - controllable aperture

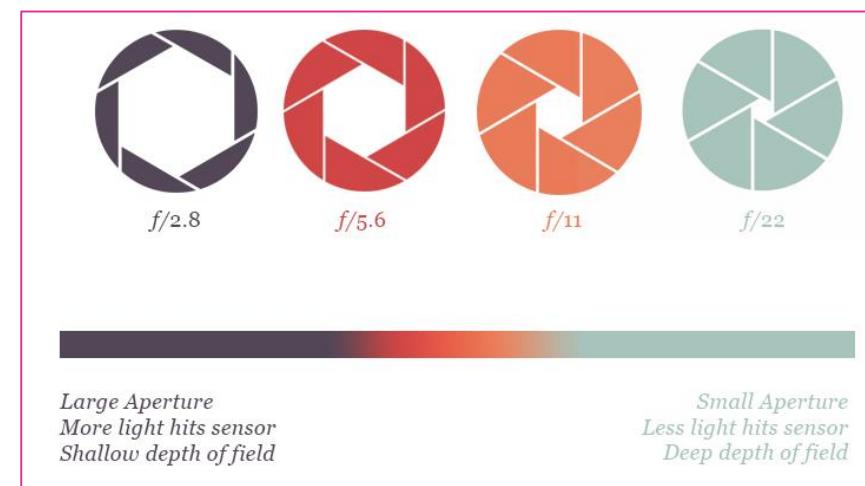


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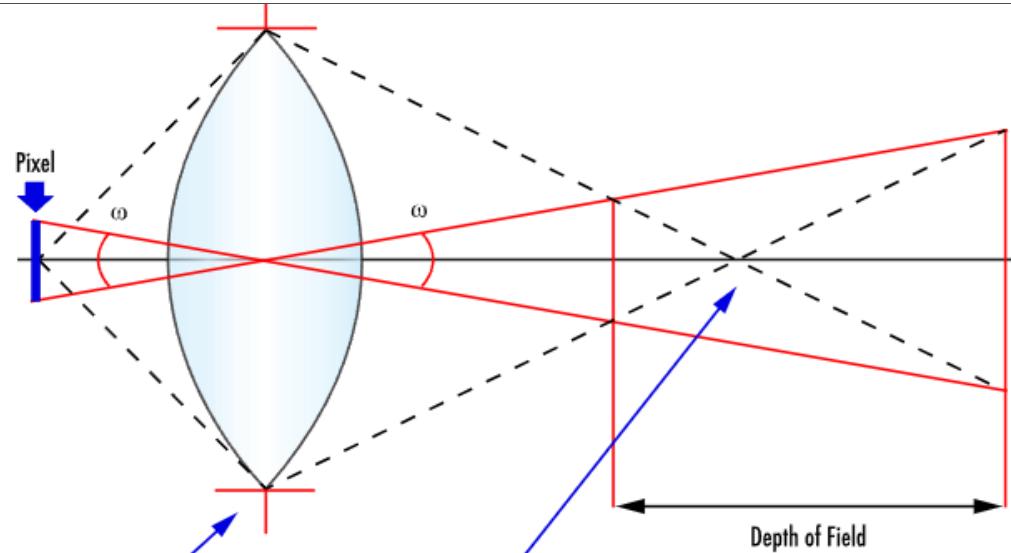
- Photography camera
  - controllable aperture



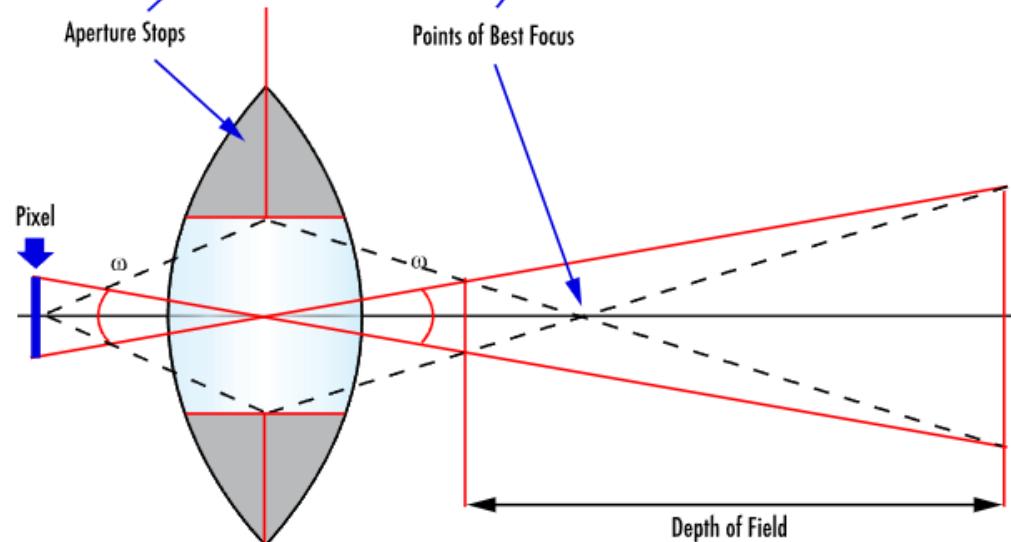
# Aperture

- Depth of Field
  - aperture  $\downarrow$  : DOF  $\uparrow$

Large Aperture



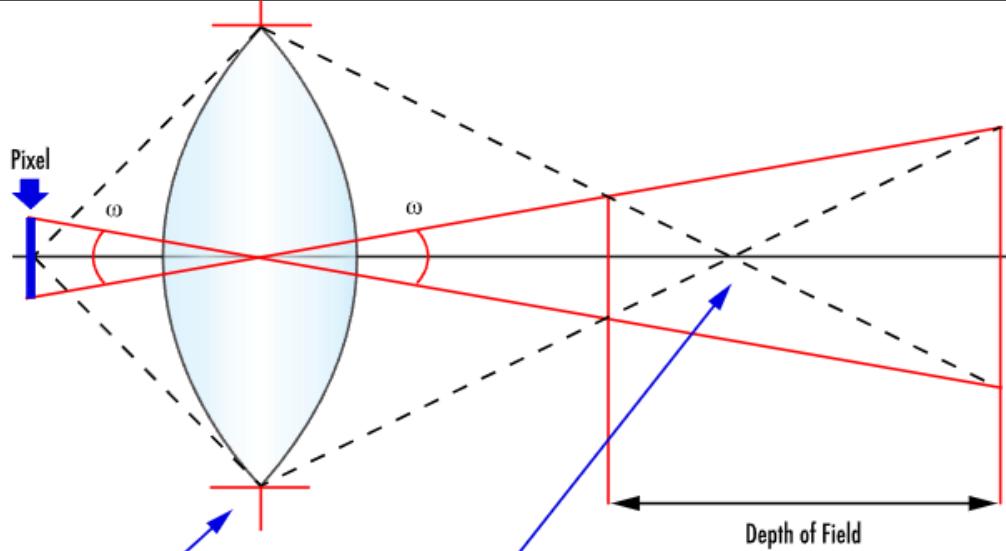
Small Aperture



# Aperture

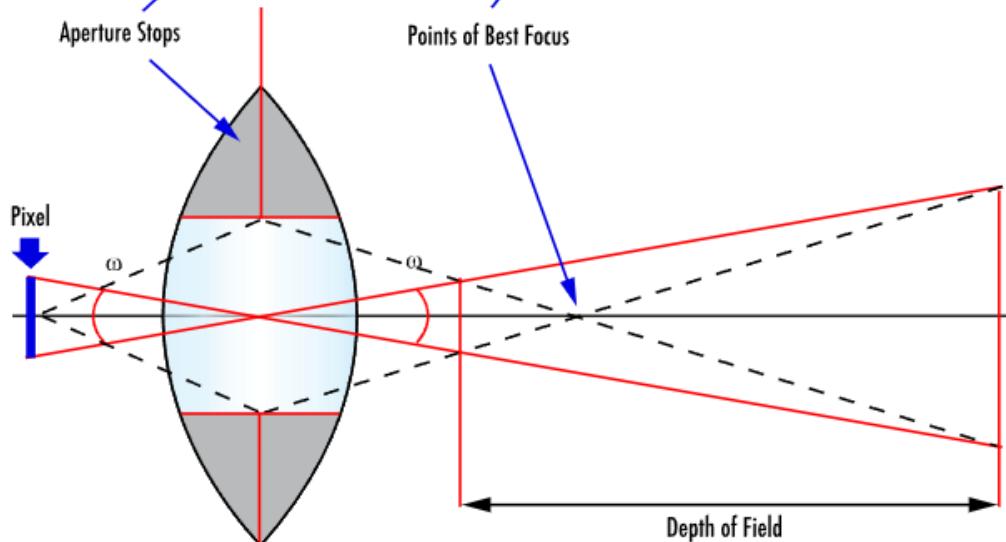
- Depth of Field
  - aperture  $\downarrow$  : DOF  $\uparrow$

Large Aperture



- Shutter
  - optical ON OFF
  - motion  $\uparrow$  : speed  $\uparrow$

Small Aperture



# Sensors

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- Passive (self-generated sensors)

- Not require external power
  - resistors
  - capacitors
  - inductors, transformers
  - antennas
  - diodes

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- Active (parametric sensors)

- Require external power
  - LED
  - solenoid
  - LiDAR
  - LCD

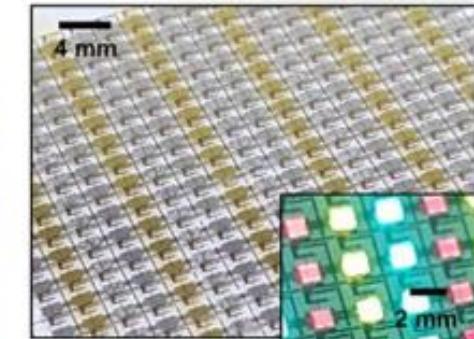
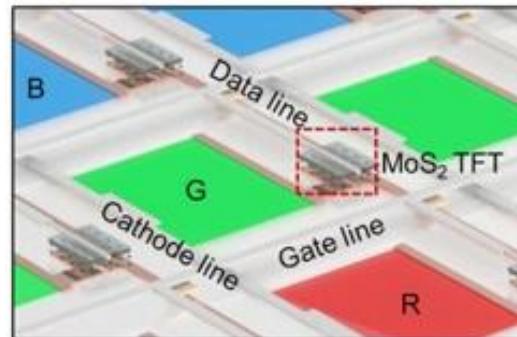
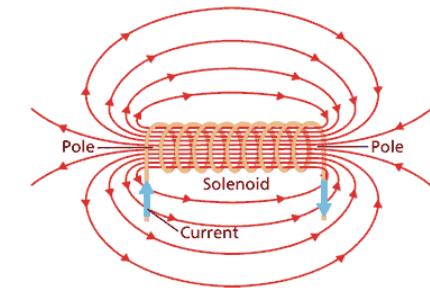
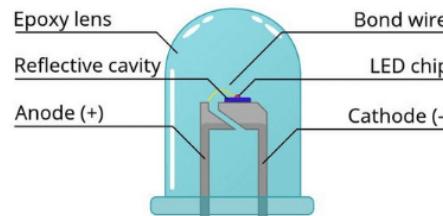
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# Sensors

- Passive (self-generated sensors)

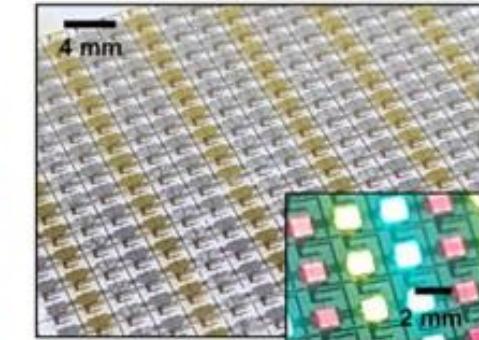
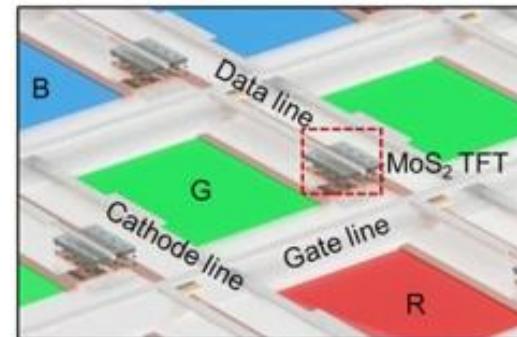
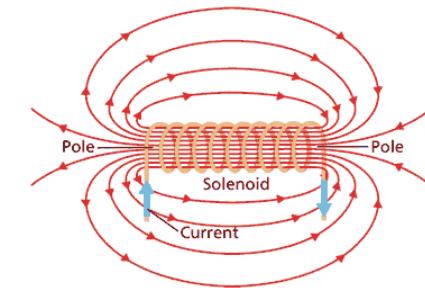
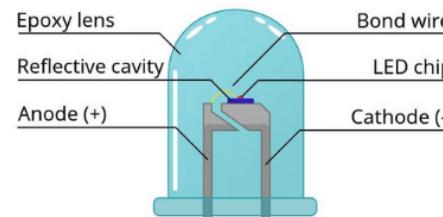
- Not require external power
- resistors
- capacitors
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- Active (parametric sensors)

- Require external power
- LED
- solenoid
- LiDAR
- LCD

- Which are energetically more efficient?

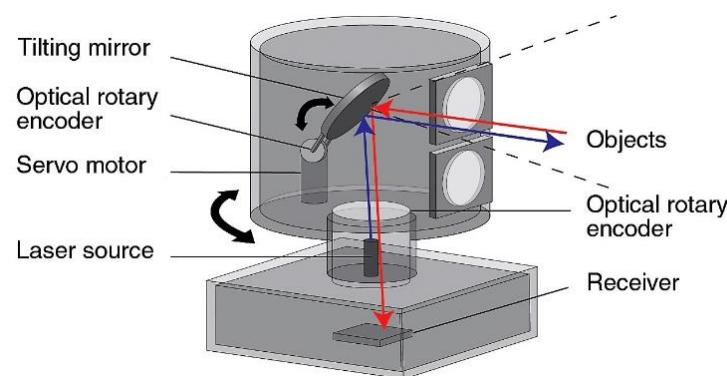
- Nature's choice



# Active sensing

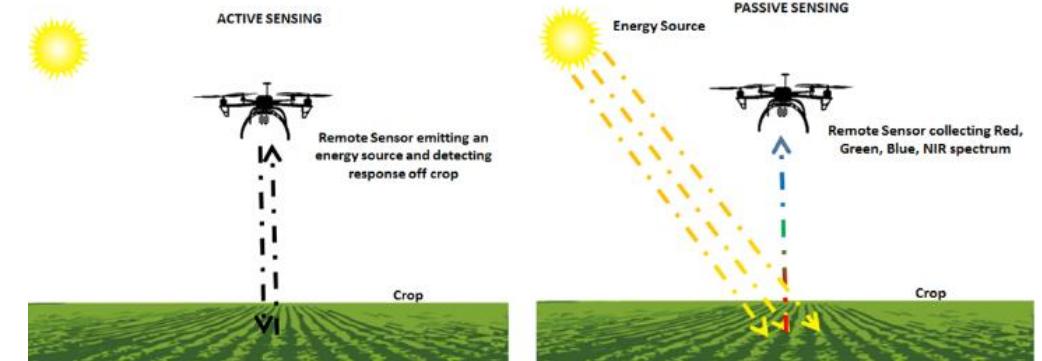
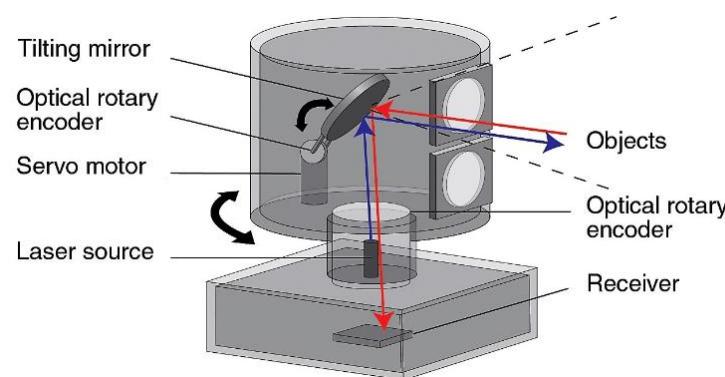
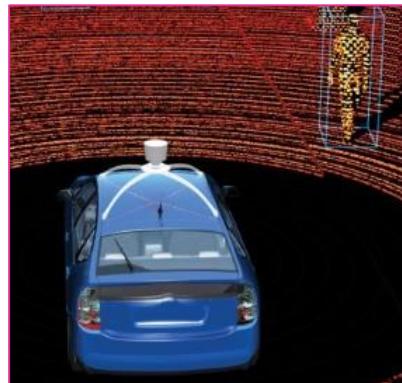
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- Precision
  - elevation mapping
- Safety
  - autonomous driving (LIDAR)
  - leader?



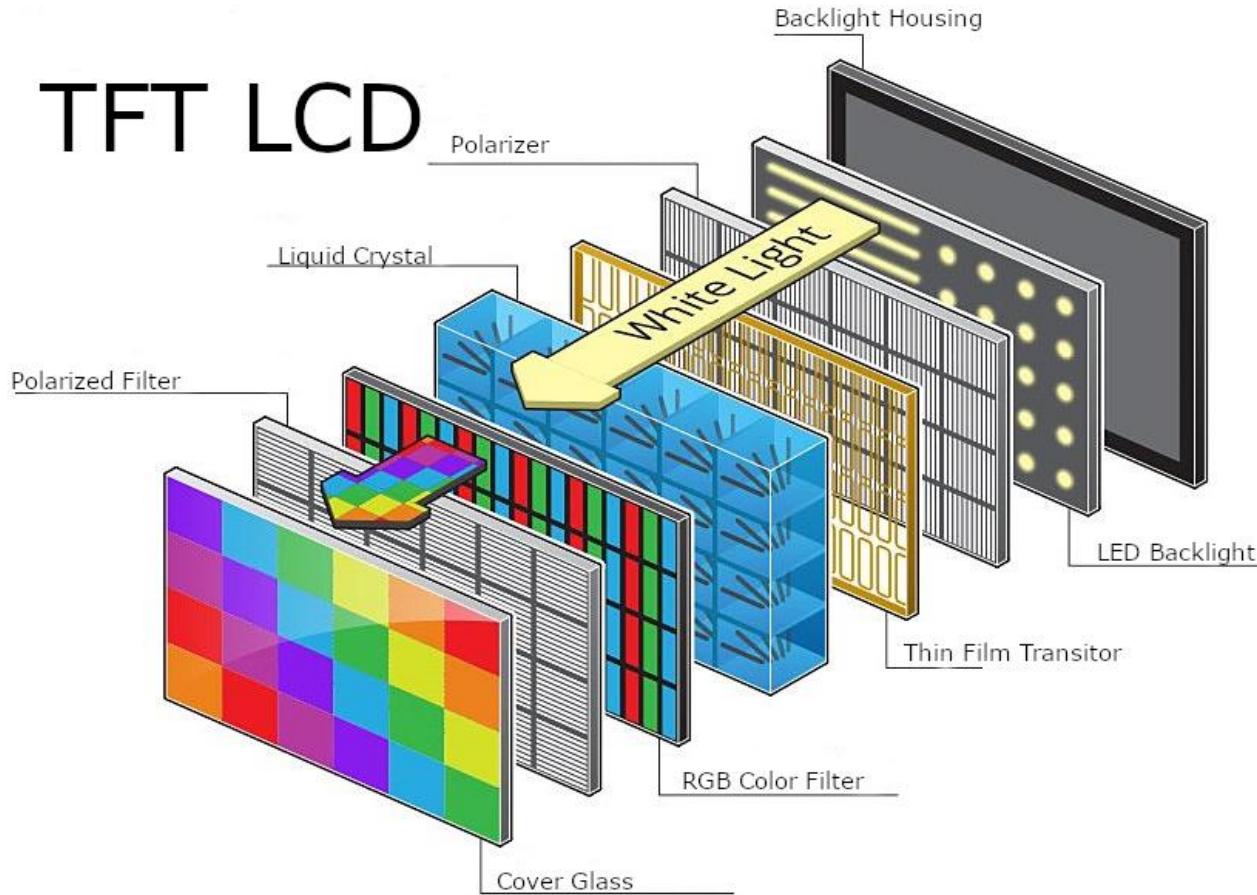
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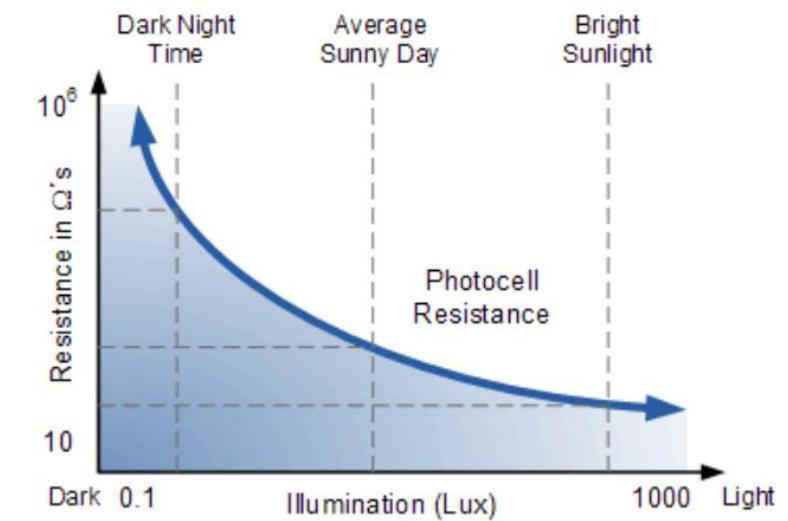
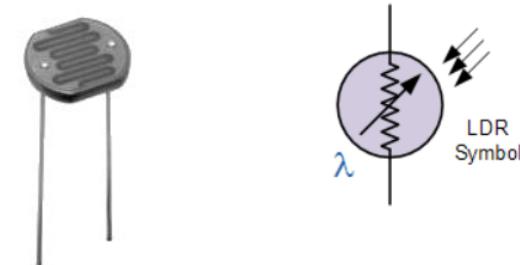
# Image display

- Active
  - LCD
    - twisted nematic liquid
    - rotate the polarization of linearly polarized light
  - thin film transistors



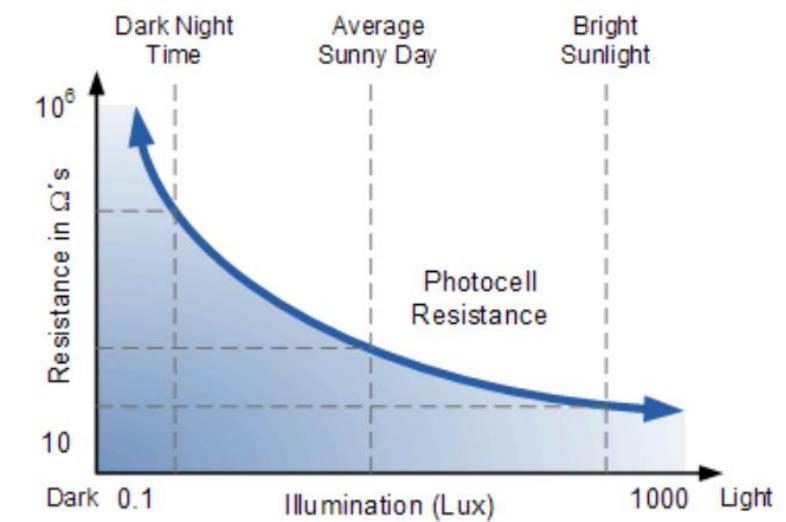
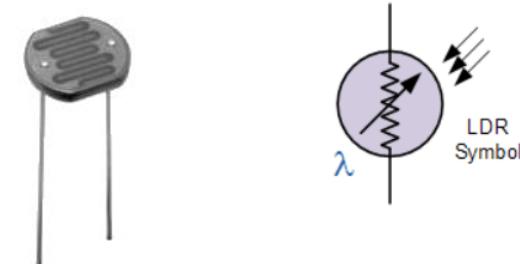
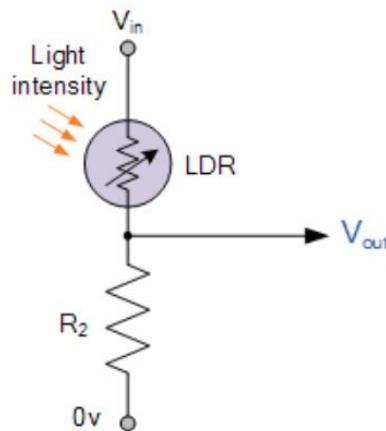
# Light sensing elements

- LDR
  - light dependent resistor
  - cadmium sulphide (CdS)
  - long response time
  - alarm detector?



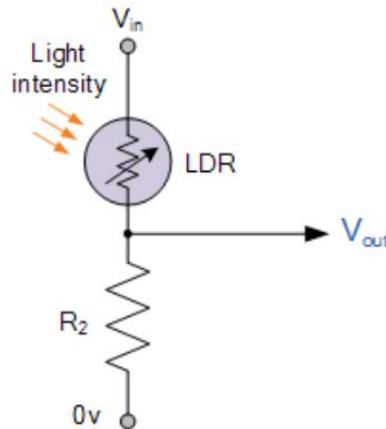
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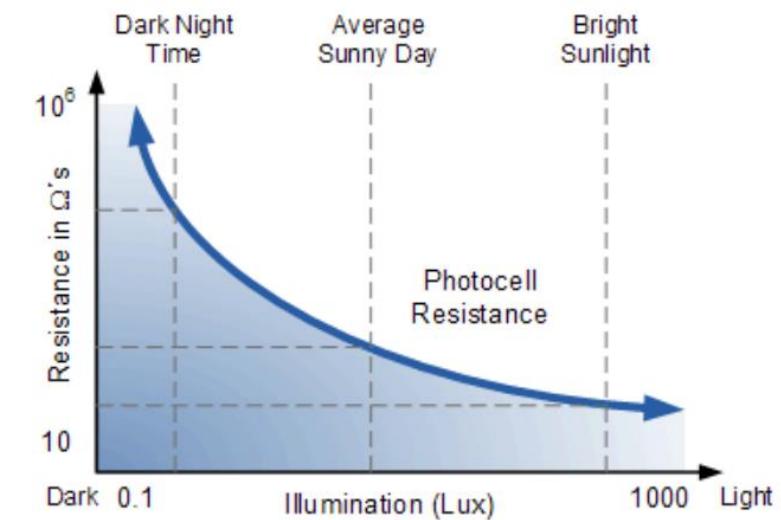
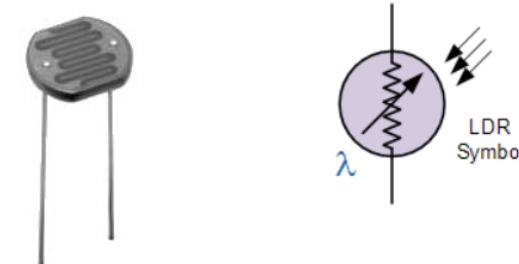


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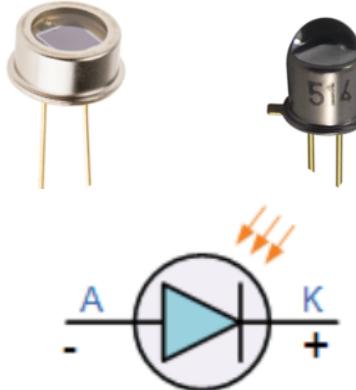
$$V_{out} = V_{in} \frac{R_2}{R_2 + R_{LDR}}$$



# Light sensing elements

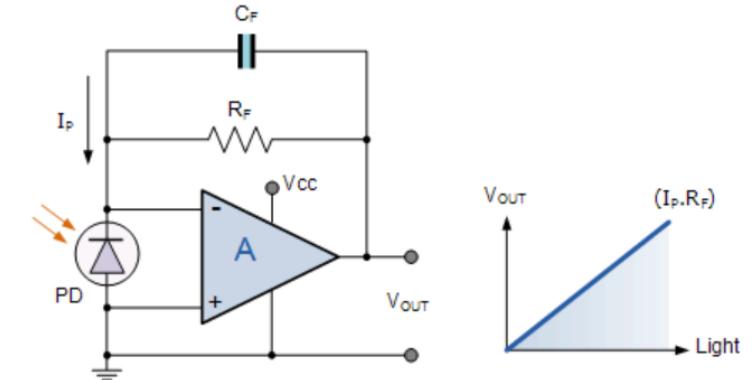
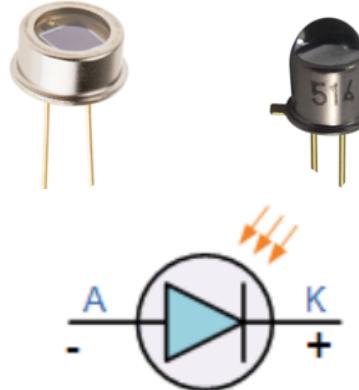
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- Photodiode
  - usual PN junctions
  - more responsive to longer  $\lambda$  (IR)
  - response time: nanosec
  - cameras, scanners, fax machines, light meters, DVD drives



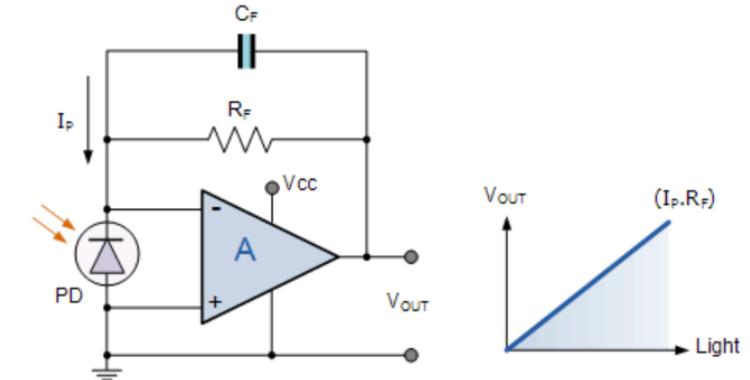
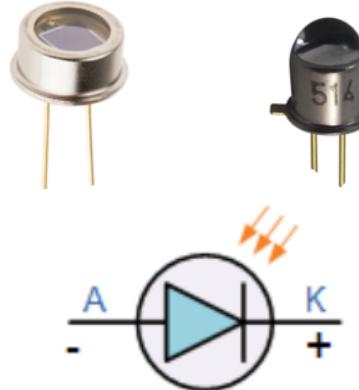
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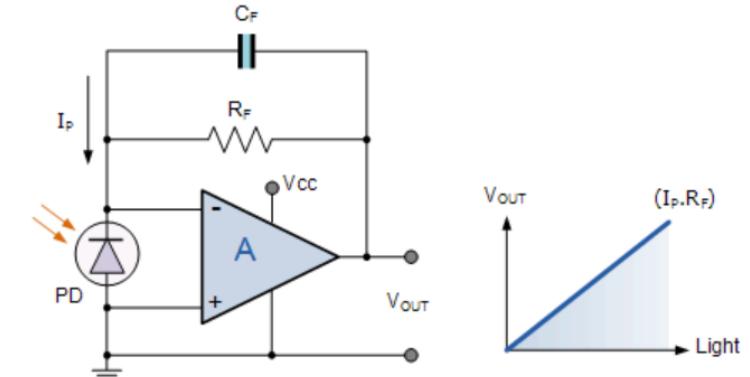
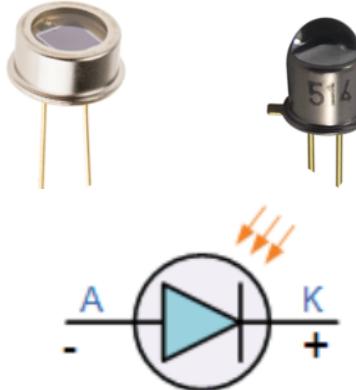
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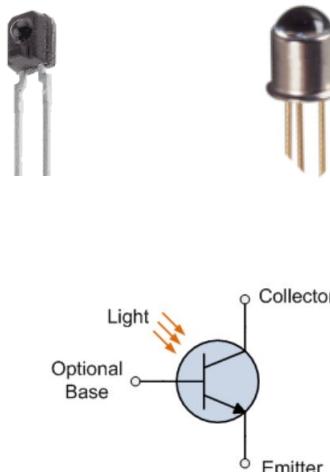
- Phototransistor
  - e.g. photodiode with inbuilt amp.
  - 100times more current gains than photodiodes
  - bipolar NPN transistor with optional base
  - opto-isolators, opto-switches fibre optics

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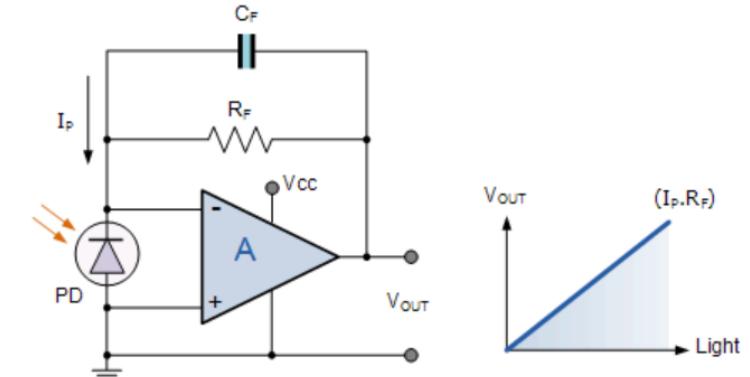
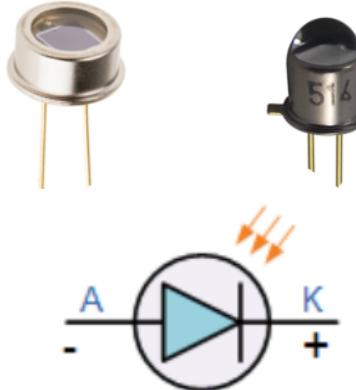


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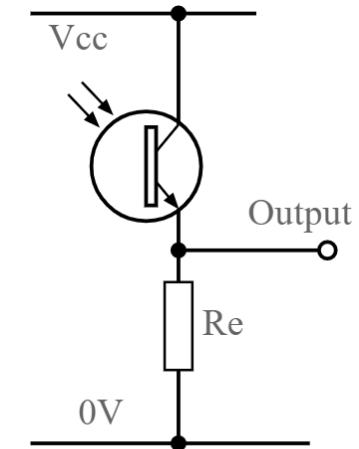
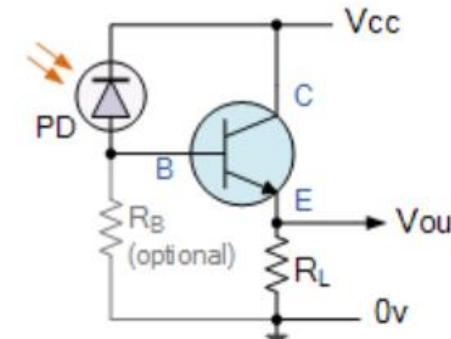
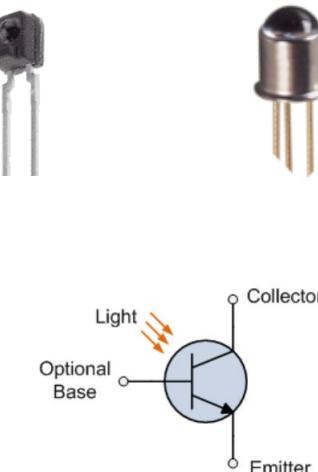


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# Signal amplification

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- High ISO
  - increased brightness sensitivity
  - better lowlight shots
  - reduced dynamics range
  - reduced color accuracy



# Signal amplification

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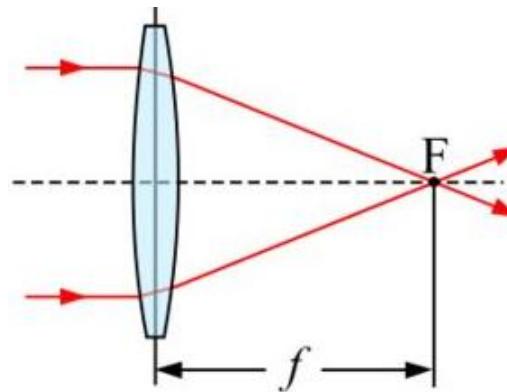
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# Light focusing element

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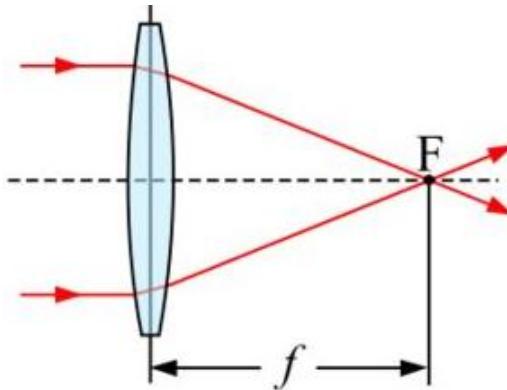
- Lens
  - Lensmaker's eq



# Light focusing element

---

- Lens
  - Lensmaker's eq



$$\frac{1}{f} = (n - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} + \frac{(n - 1)d}{nR_1R_2} \right]$$

$f$  is the focal length of the lens

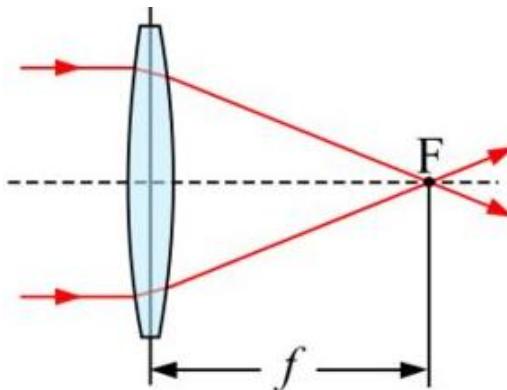
$n$  is the refractive index

$R_1 R_2$  radius of curvature

$d$  is the thickness of the lens

# Light focusing element

- Lens
  - Lensmaker's eq



$$\frac{1}{f} = (n - 1) \left[ \frac{1}{R_1} - \frac{1}{R_2} + \frac{(n - 1)d}{nR_1R_2} \right]$$

$f$  is the focal length of the lens  
 $n$  is the refractive index  
 $R_1$   $R_2$  radius of curvature  
 $d$  is the thickness of the lens

- Refractive index

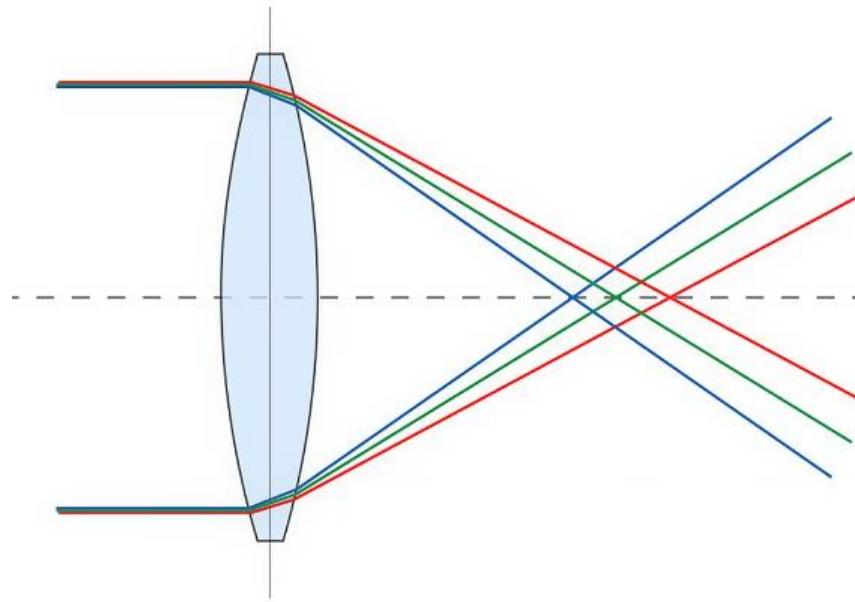
$A, B$ : material constants.

$$n(\lambda) = A + \frac{B}{\lambda^2}$$

# Single lens

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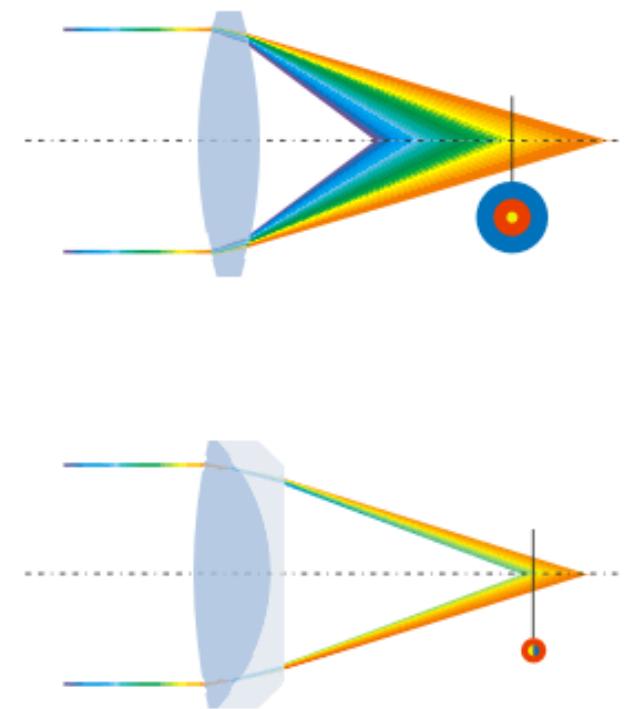
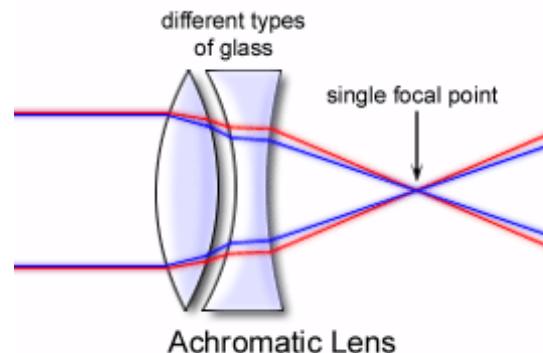
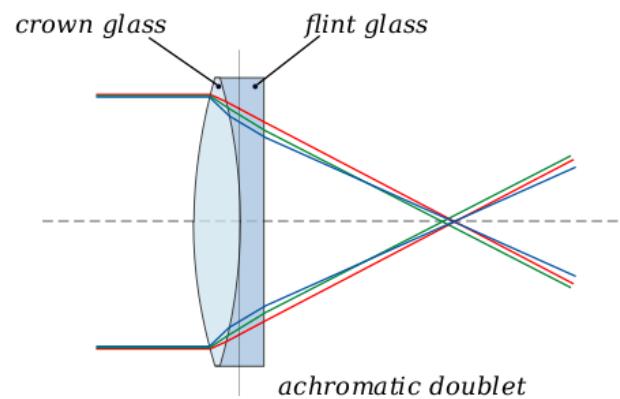
- Chromatic aberrations
  - failure of lens to focus all colors to the same point
  - fringes of color at image boundaries



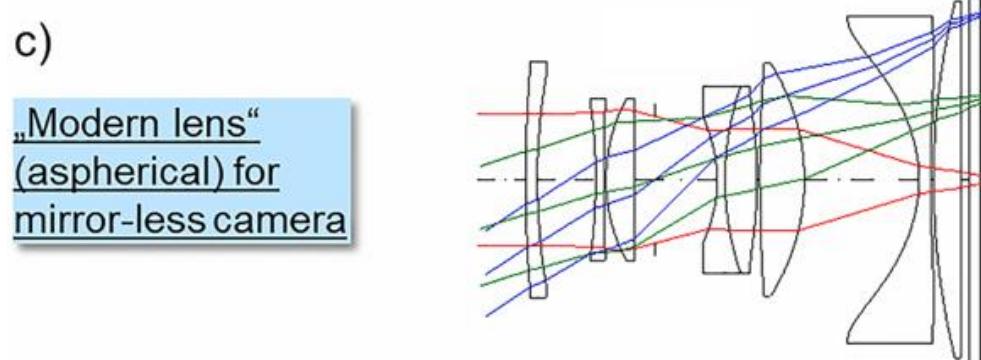
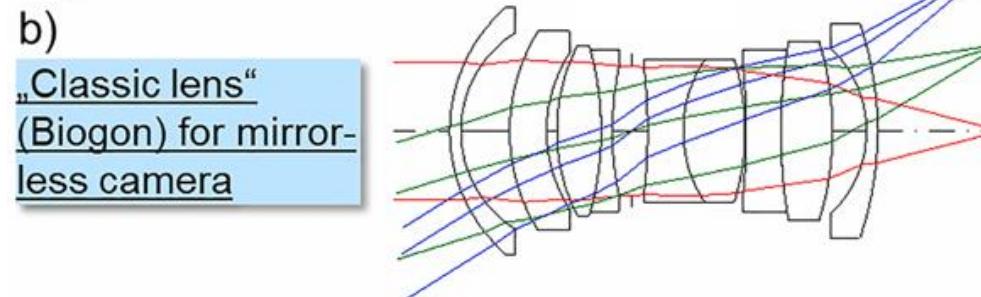
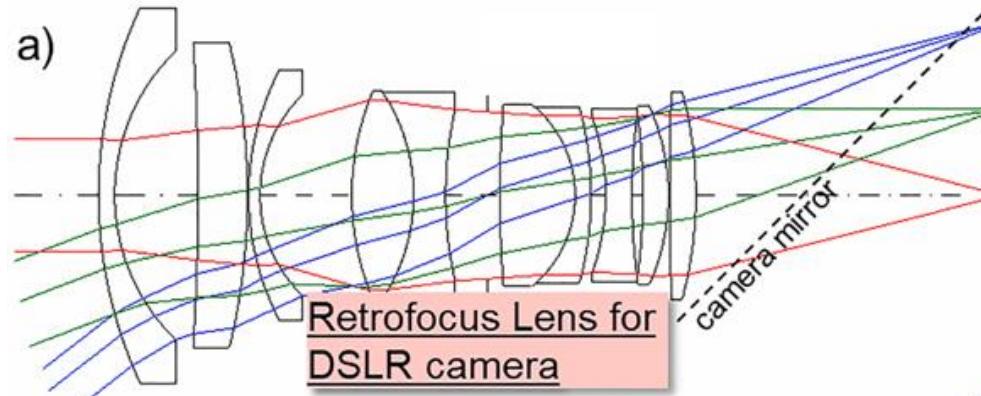
# Double lens

- Achromatic doublet
  - Littrow doublet :  $R_1 = R_2, R_3 = -R_2$

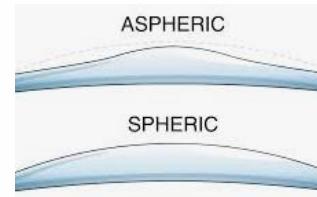
- Fraunhofer doublet: small air between  $R_2, R_3$ 
  - more degree of freedom in design



# Multi-Lens



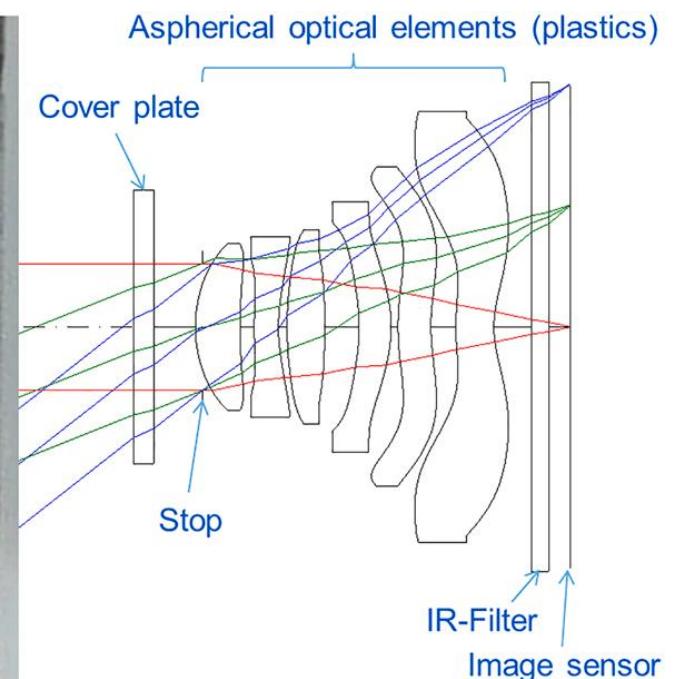
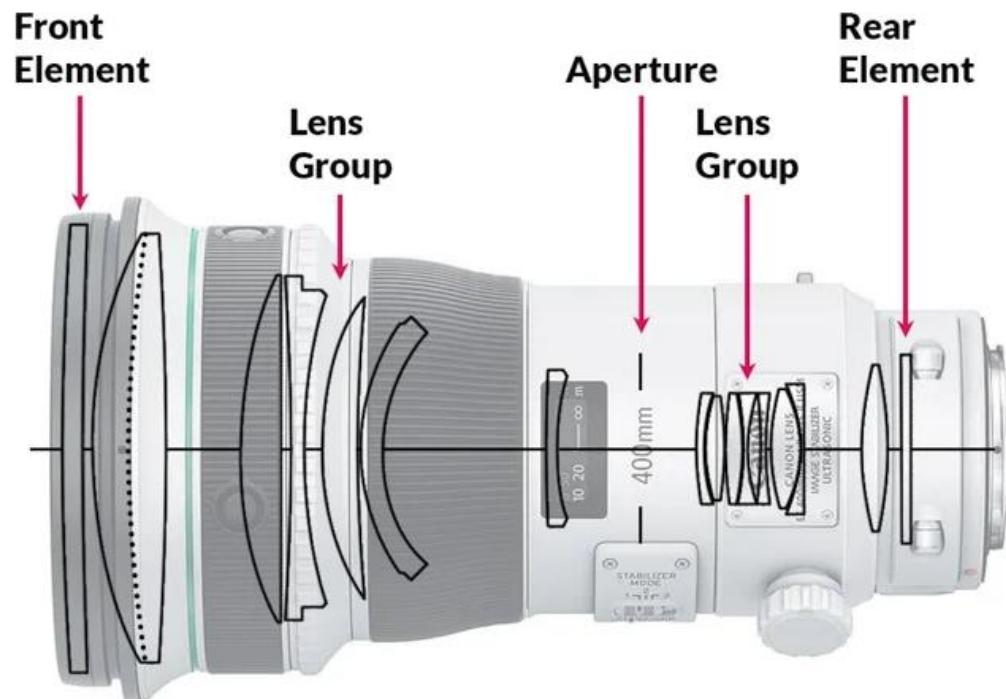
DSLR (digital single line reflex)



mirror-less system camera

# Cameras

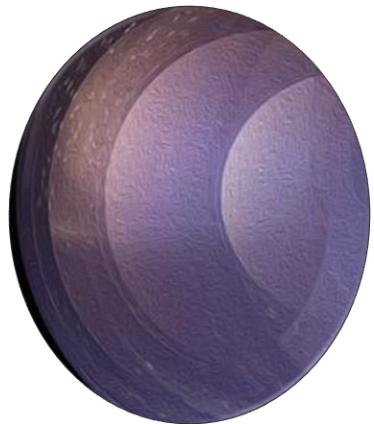
- Eagle Vs Hummingbird



# High precision lens

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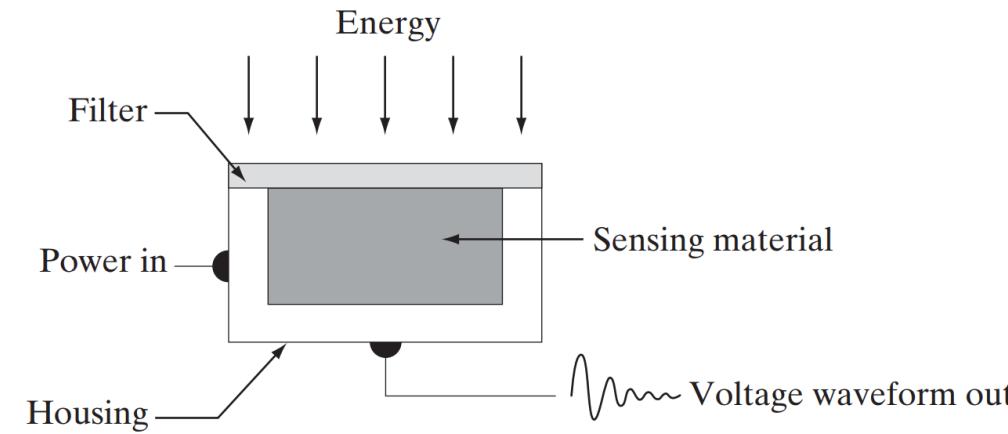
- Scientific and precision imaging



# Image sensing

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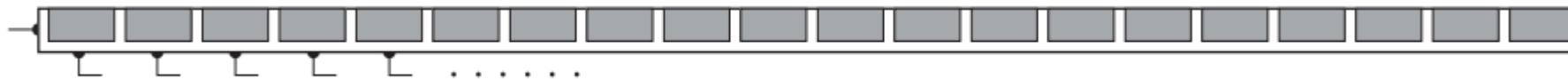
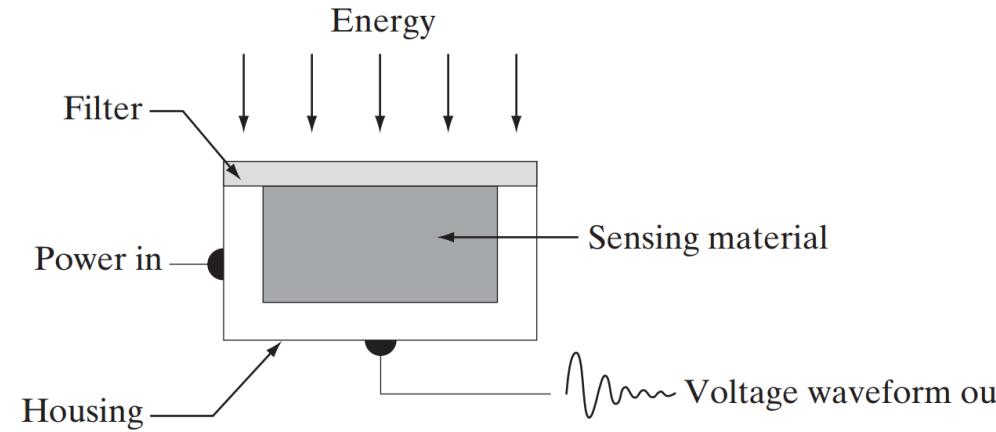
- Array sensor
  - 1D, 2D



# Image sensing

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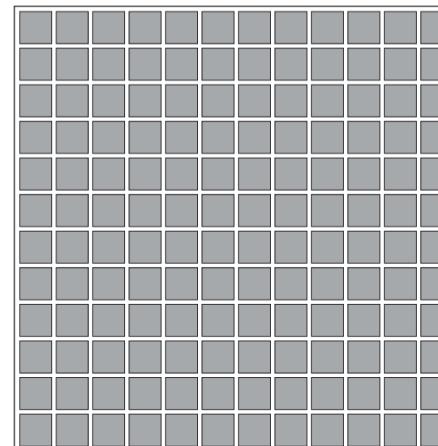
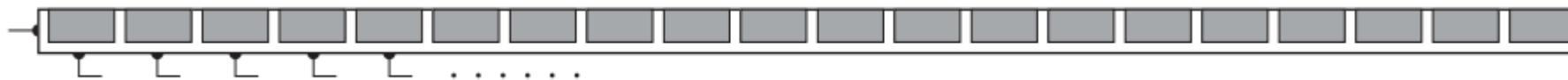
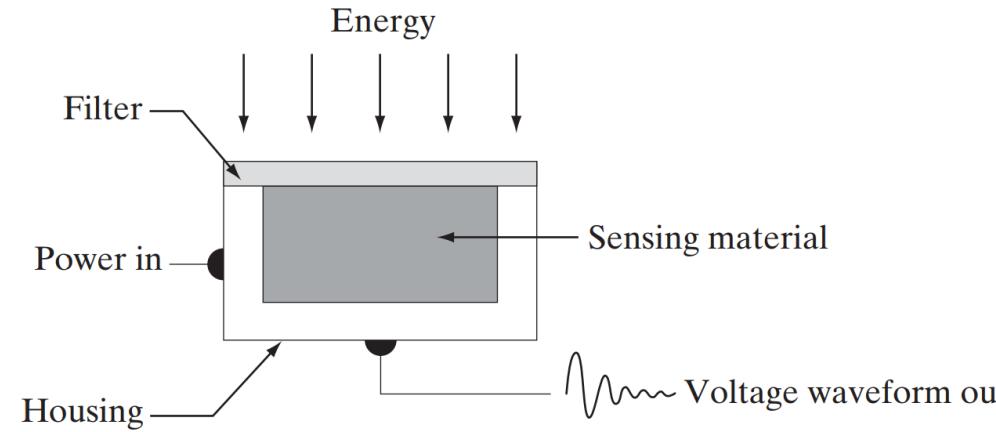
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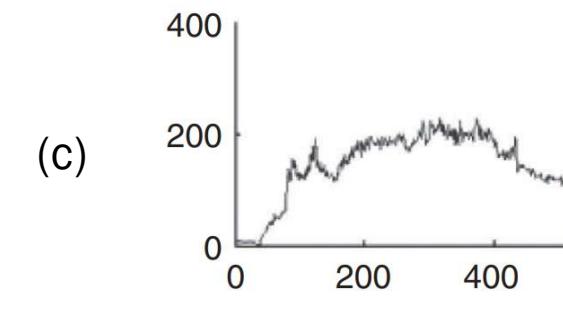
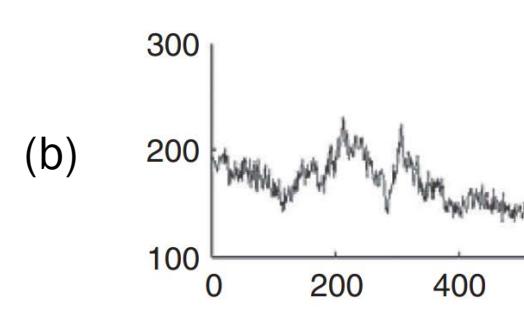
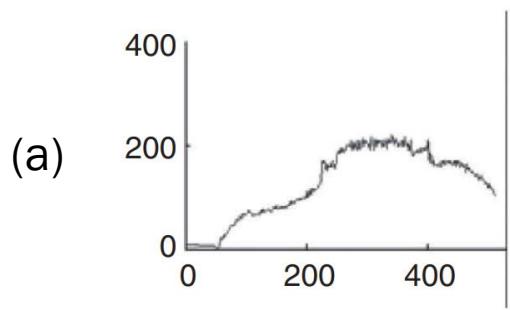
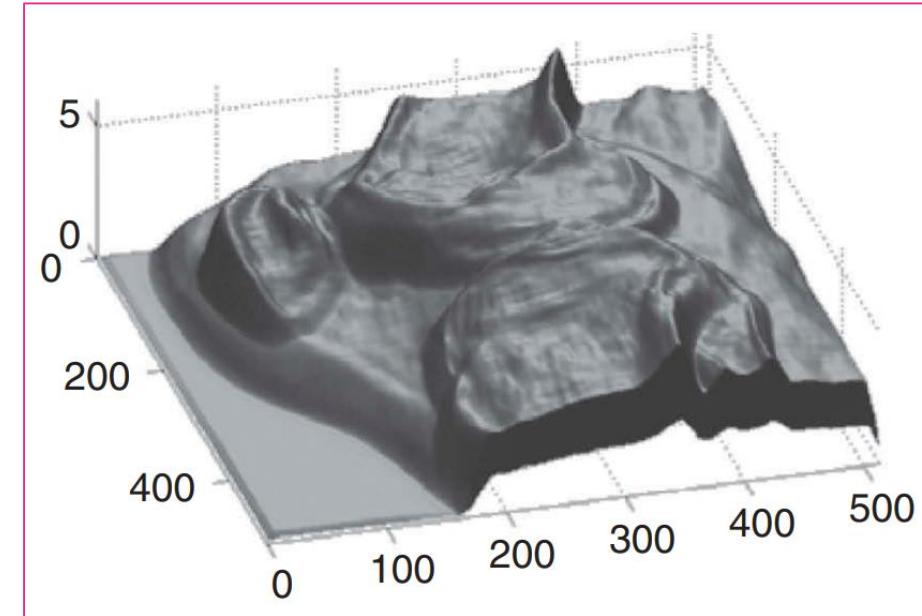
# Image sensing

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- Array sensor
  - 1D, 2D

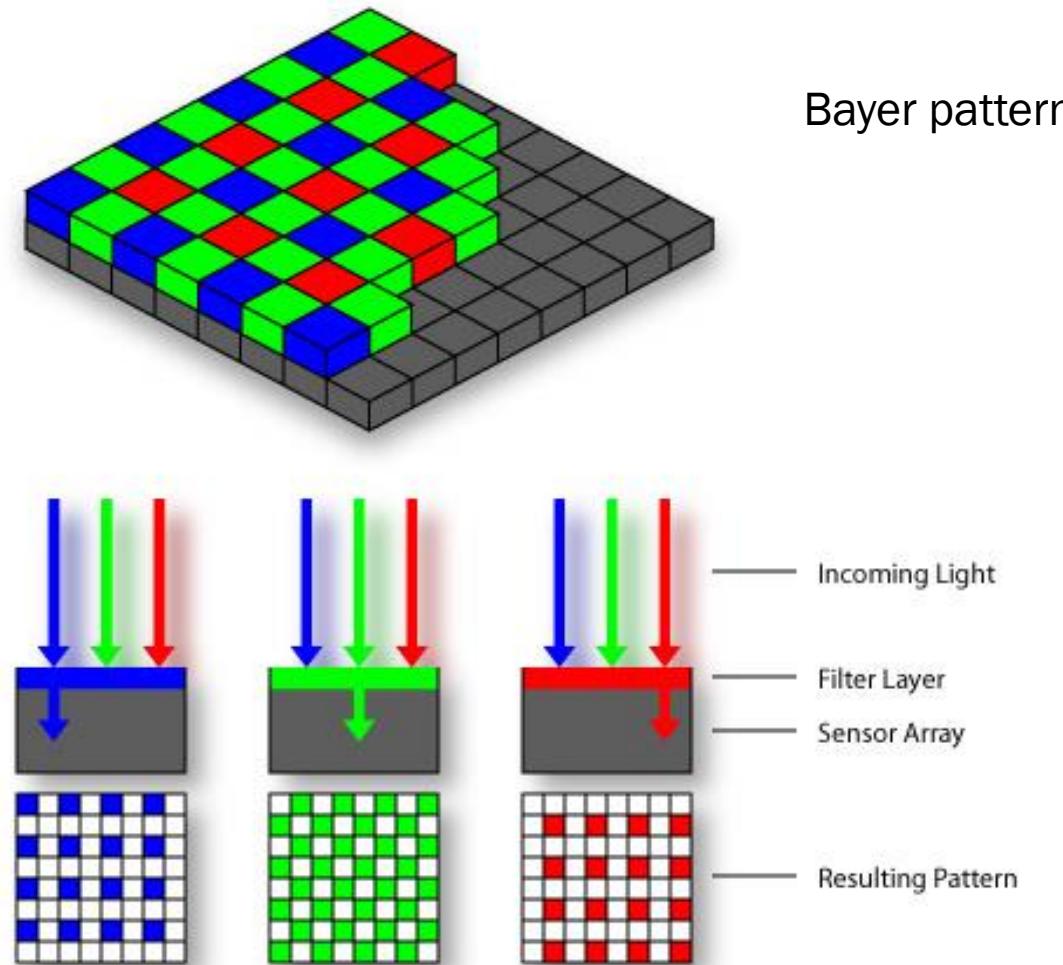


# Image representations

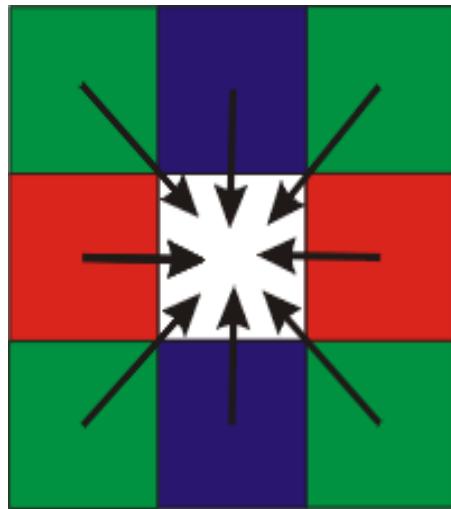


# Color sensing

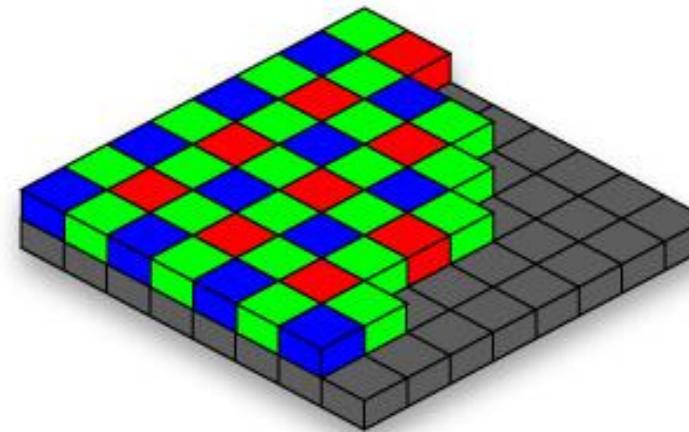
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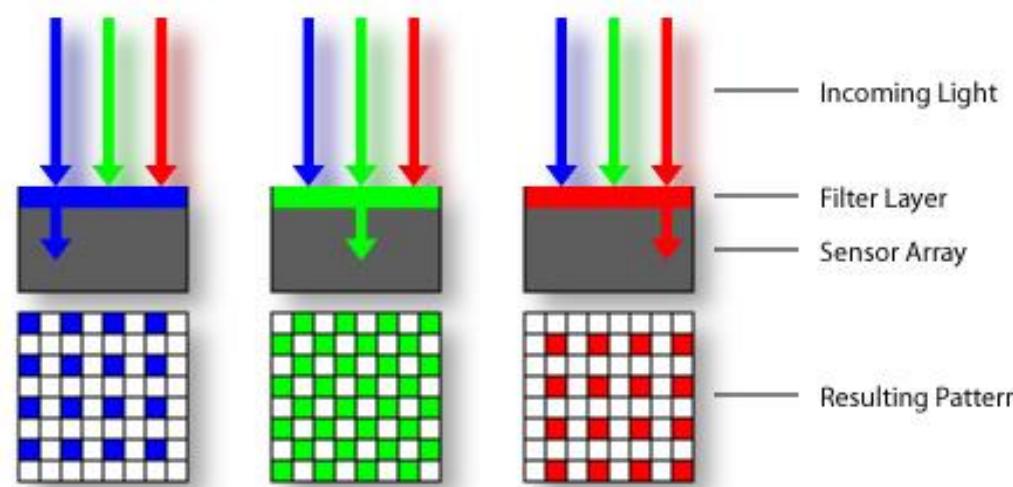
# Color sensing



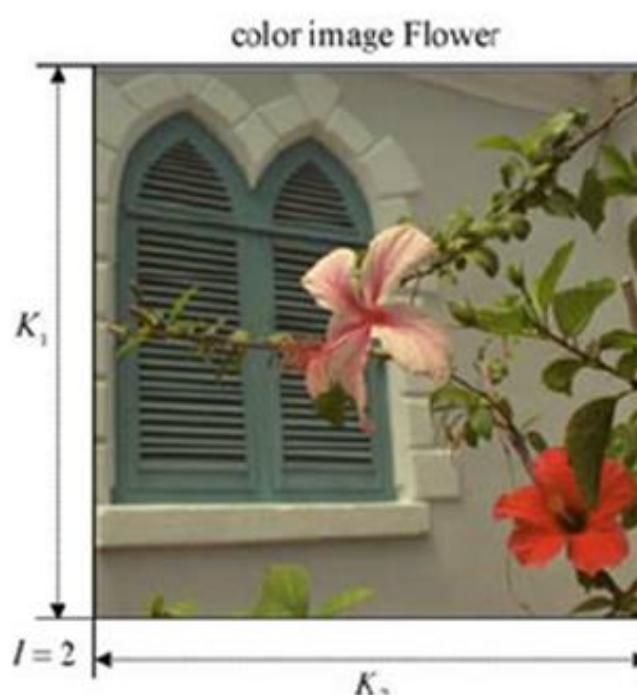
Estimate the color



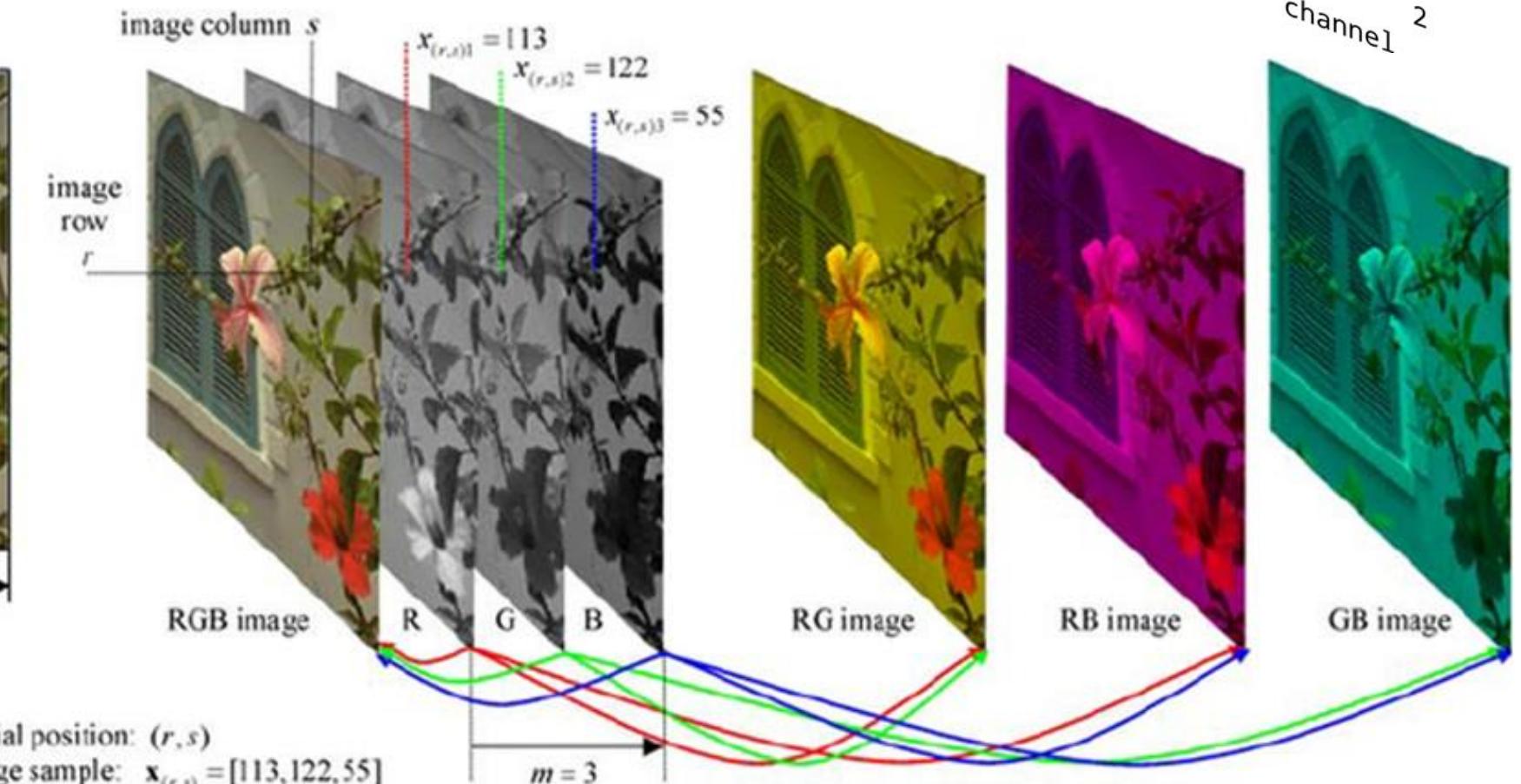
Bayer pattern



# Image representations



number of image rows:  $K_1$   
number of image columns:  $K_2$   
image dimension:  $I$   
number of color channels:  $m$



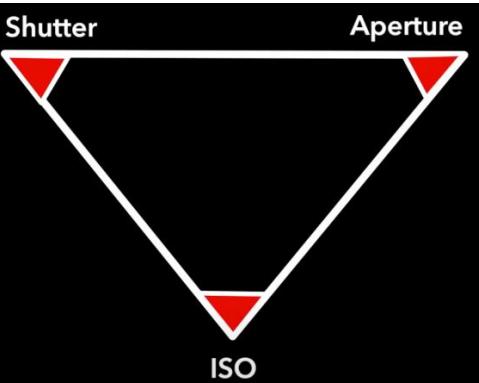
			column
			0 1 2
row	0	.392 .482 .576	
	1	.478 .63 .169	.263 .376 .451
2	0	.580 .79 .263	.44 .376 .478 .561
	1	.373 .60 .443	.569 .674

## ❑ The Exposure Triangle

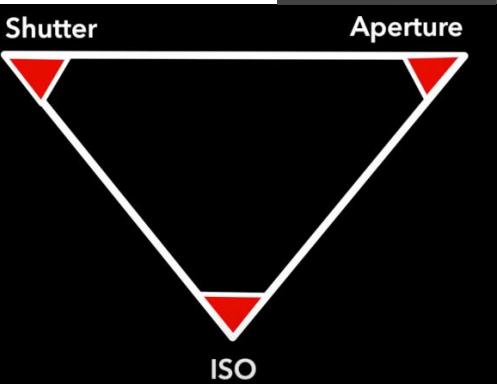
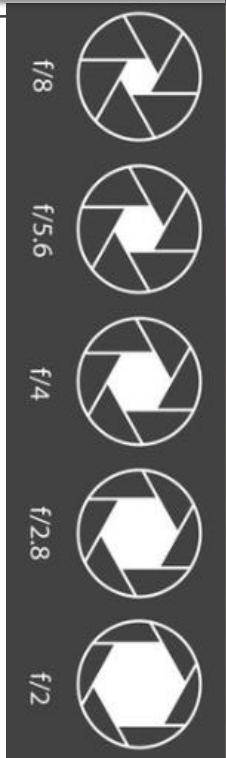
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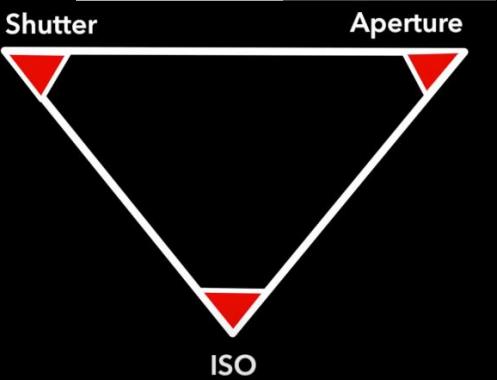
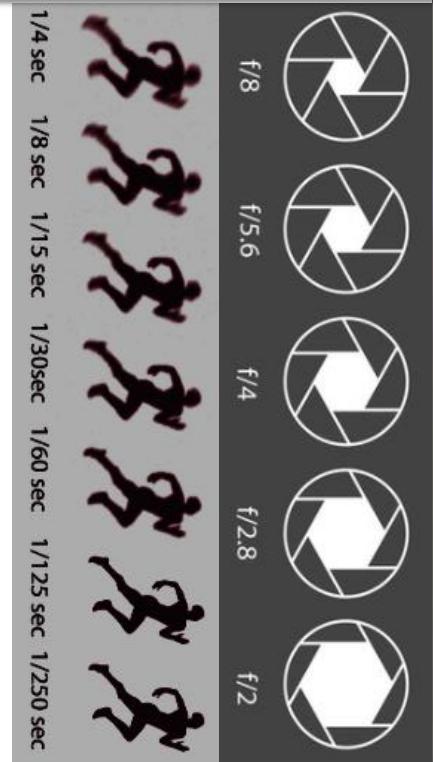
## ❑ The Exposure Triangle



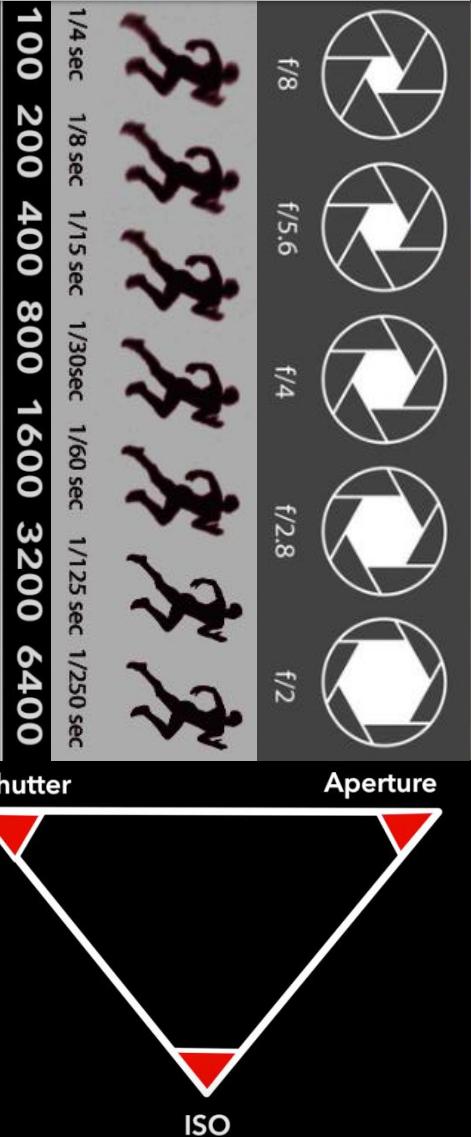
## ❑ The Exposure Triangle



## ❑ The Exposure Triangle



## ❑ The Exposure Triangle



# Conclusion

- Camera systems
- Image representation

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- Camera systems
- Image representation

## ❑ Camera systems

- Aperture
- Lens
- Shutter
- Light sensors

## ❑ Digital image representation

- Grey
- Color
- Matrix (tensor)